

Introduction

- Monitoring is often the most overlooked aspect of a reclamation project
- Site visits during and after reclamation activities
- Incorporate monitoring costs into the budget at the beginning of a project

Monitoring

Purposes

- Assess if reclamation objectives are on track or have been met
- Locate problems, if any
- Develop remediation recommendations, if needed
- Evaluate successes, failures, and determine cost-effectiveness

Monitoring

Purposes

- Verify contract compliance
- Assure adequate data are available to guide remedial actions, if needed
- Provide for future cost savings

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Monitoring Plan

- Monitoring plan should be written and included as a section in the reclamation plan before implementation begins
- Plan should be “tailor-made”

Monitoring

Key Elements

- Clearly identify the reclamation objectives
- Outline and describe monitoring techniques to be used, including a monitoring schedule
- Clearly define success criteria
- Identify reference area
- Summarize and report monitoring results

What to Monitor?

- Soil erosion
- Vegetation establishment
- Wildlife use
- Climatic variables (e.g. precipitation, soil moisture, air and soil temperature)
- Incursions onto site/subsequent disturbances

Monitoring

Techniques

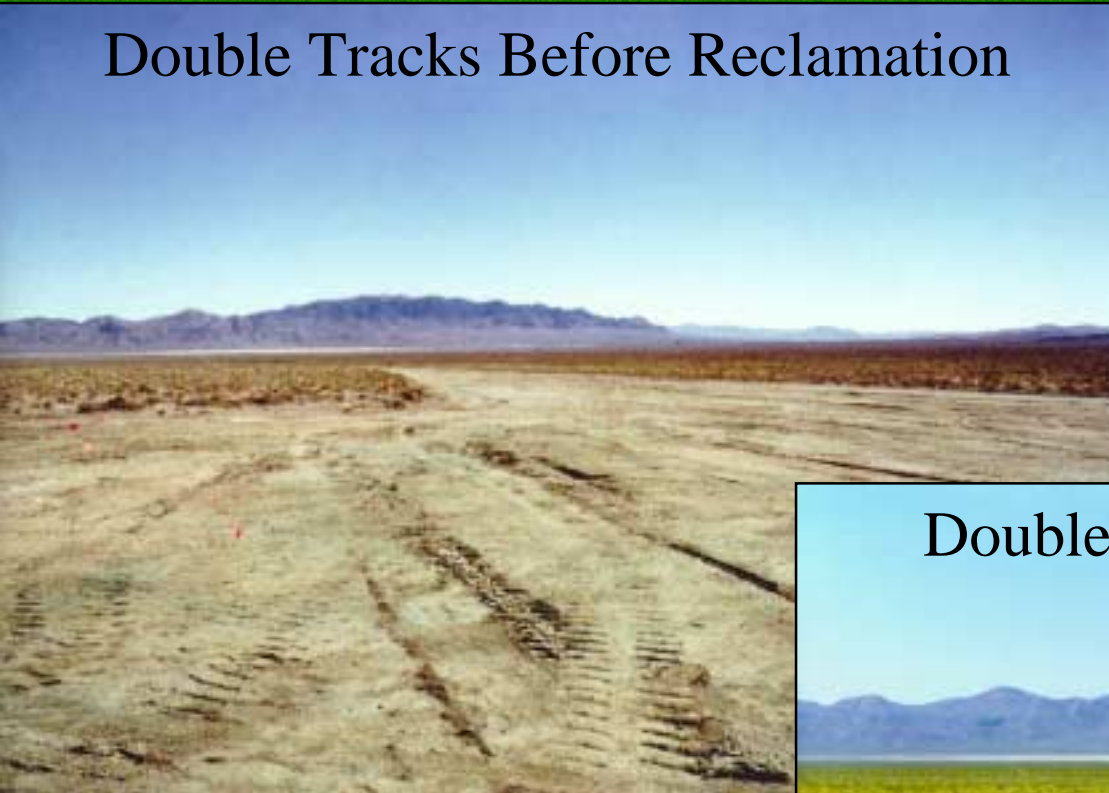
- Qualitative vs. Quantitative
 - Reclamation objectives
 - Reporting requirements
 - Budgetary constraints
- May be best to use combination of both techniques

Techniques

- Qualitative monitoring
 - Reconnaissance site visits
 - Observe and document site conditions
 - Important to take good notes
 - Standardized checklist
 - Digital video camera
 - Color photographs from standardized photo points

Monitoring

Double Tracks Before Reclamation



Double Tracks After Reclamation



Monitoring

Techniques

- Quantitative monitoring
 - Taking measurements or counts



Monitoring

Techniques

- Soil erosion



Table 4-1. Example of a soil-erosion rating and classification form for assessing erosion status in the field.

Rating Value	A Surface Litter	B Pedestalling	C Rills < 23 cm (9 in)	D Rills > 23 cm (9 in)	Totals
1	Accumulating in place	No visual evidence	No visual evidence	No visual evidence	
2	Slight movement	Slight pedestalling	Rills in evidence at intervals > 3 m (10 ft)	Rills in evidence at intervals > 3 m (10 ft)	
3	Moderate movement	Small rock and plant pedestalling	Rills at 3 m (10 ft) intervals	Rills at 3 m (10 ft) intervals	(A+B+C+D)
4	Extreme movement	Pedestalling evident, plant roots exposed	Rills at 1.5 – 3 m (5 – 10 ft) intervals	Rills at 1.5 – 3 m (5 – 10 ft) intervals	
5	Very little remaining litter	Most plants and rocks pedestalled and roots exposed	Rills at < 1.5 m (5 ft) intervals	Rills at < 1.5 m (5 ft) intervals	
Example:	Surface Litter Rating: 3	Pedestalling Rating: 3	Rills < 23 cm Rating: 3	Rills > 23 cm Rating: 3	12.0*
* Number Rating for Totals:		Total Rating Value Erosion Condition Class			
		0.0 – 4.0 Stable			
		4.1 – 8.0..... Slight			
		8.1 – 12.0..... Moderate			
		12.1 – 16.0..... Critical			
		16.1 – 20.0..... Severe			

Monitoring

Techniques

- Vegetation measurements
- Intent is brief overview (Bonham, 1989; Elzinga et al., 1998; LCTA Manuals)
 - density
 - cover
 - frequency
 - biomass
 - species richness
 - species diversity

Monitoring

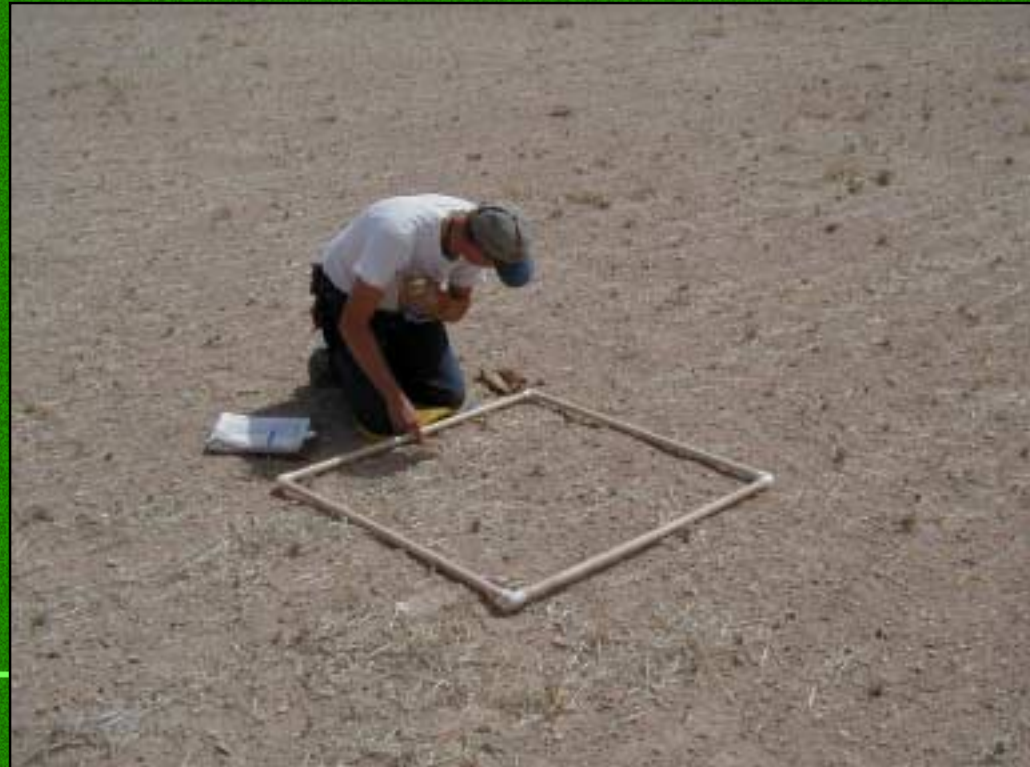
Techniques

- **Density (# counting units per unit area)**
 - Counting unit should be consistent and distinguishable
 - Limited measure of community dominance
 - Easy to understand
 - Useful for measuring seedling emergence
 - Useful for monitoring plant responses to various vegetation treatments
 - Most sensitive to changes caused by mortality or recruitment

Monitoring

Techniques

- Density estimates
 - plot (quadrat)
 - distance
 - line transect



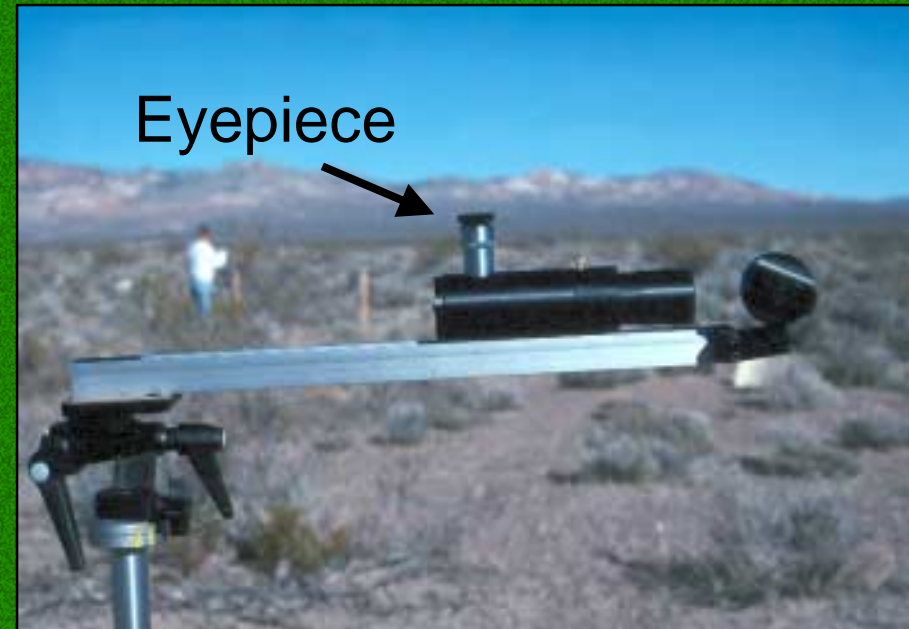
Techniques

- Cover (percentage of ground surface covered by vegetation material)
 - Commonly measured quantity in vegetation sampling
 - Different life forms can be evaluated in comparable terms
 - Important factor in erosion models
 - Not a very useful measure for seedlings
 - Cover changes through growing season

Monitoring

Techniques

- **Cover estimates**
 - line-intercept
 - point-intercept
 - ocular estimate
 - mapping and charting
 - cover class (e.g. Daubenmire scale)
 - photographic methods



Cover scope

Monitoring

Techniques

- Frequency (# of times a species is present in given # of quadrats)
 - Usually expressed as a percentage
 - Easiest and quick quantitative measurement
 - Most difficult to interpret
 - Dependent on shape and size of quadrat
 - Useful for detecting changes in vegetation structure

Techniques

- **Frequency measures**
 - plot, nested plot, and complementary plot are most common methods
 - point sampling
 - step-point method
 - loop method

Monitoring

Techniques

- Biomass (measure of “primary production” or the energy fixed by plants)
 - Necessary for proper understanding of ecosystem dynamics
 - Vegetation composition (dry weight) one of best indicators of species importance within a plant community
 - Variable from year to year
 - Labor-intensive and costly

Monitoring

Techniques

- Biomass measures

- Direct

- Harvesting/clipping/mowing
 - Oven or air-dry

- Indirect

- Reference unit
 - Weight estimates and double sampling
 - Correlations between various plant characteristics (e.g. leaf length, crown area, plant volume, cover) and biomass



Monitoring

Techniques

Species Diversity

- Species richness (# species per unit area)
- Species diversity (evenness of abundance among the species)
 - Shannon-Weiner diversity index
 - MacArthur-Wilson diversity index

Techniques

- **Sample size**
 - Depends on level of accuracy or precision you need or are required to provide and the resources you have to do the monitoring
 - Statistical formulas for determining adequate sample size (Bonham, 1989)

Monitoring

Techniques

- Common equipment
 - Quadrats
 - Measuring tapes
 - Cover scopes
 - Laptop computer
 - Hand-held palmtop computer (data sheets)



Techniques

- **Data analysis**
 - Descriptive statistics (e.g. mean, standard deviation)
 - Regression
 - Analysis of variance and mean separation procedures
 - Depends on reclamation objectives, reporting requirements, bond releases, or potential legal challenges

Monitoring

Techniques

- **Monitoring timing**
 - During implementation phase
 - Three to five years minimum after implementation
- **Monitoring frequency**
 - Reclamation objectives
 - Site accessibility
 - Budgetary constraints
 - Time of year

Monitoring

Success Criteria

- Used to evaluate whether reclamation objectives have been met or not
- If criteria are not met, remedial action should be taken
- Need to be achievable and somewhat flexible
- May be dictated by government regulations or stakeholders

Monitoring

Reference Areas

- Used to determine or approximate pre-disturbance state of disturbed site
- Data from reference area used to develop seed mixes and transplant needs and for comparison with data collected from revegetated sites
- LCTA plots



Monitoring

Reference Areas

- Criteria for comparing reference and revegetated areas (Vogel, 1987)
 - Site factors (e.g. elevation, slope, aspect) similar
 - Composed of same plant life-forms
 - Similar management and long-term integrity
 - Similar soil characteristics
 - Both sites are able to produce similar vegetation
 - If possible, be within 20 miles of each other
 - Similar sampling design

Monitoring

Reporting Monitoring Results

- Results should be summarized and communicated to the right people via formal reports, informal reports, or memos to file
- Report format may be pre-determined and should contain answers to the following questions:
 - Are reclamation objectives on track or have they been met?
 - Are there any problems (e.g. erosion, dead plants)?

Monitoring

Reporting Monitoring Results

- Are any remedial actions needed?
- What techniques were successful and why?
- What techniques failed and why?
- What was the cost-effectiveness of each technique?
- Were contract specifications met?
- Were there any inconsistencies between what was written in the reclamation plan and what actually occurred during implementation?

Questions